PART II

A SCIENTIFIC COMPUTER

CRITERIA, EVALUATION AND SELECTION

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SUMMARY

A previous report discussed the present and future computational problems and the resultant need for a new computer. It is the basis upon which criteria were developed and commercial computers evaluated to meet the requirements of the system. This report discusses these criteria and indicates which commercial device is the best for this application. Several other applicable machines were evaluated in the selection process.

The computer, considered most applicable, is the Remington Rand Univac 490. It is a real time computer specifically designed to function in a complex of multiple input and output devices. The forerunner of this machine was built for the U. S. Navy. The recommended commercial version has been completed and is in operation at the Remington Rand factory in Saint Paul.

A. THE BASIS FOR THE SELECTION OF A COMPUTER

1. General Criteria

Eighteen criteria were chosen as a basis for the evaluation and selection of a computer. Some, as the discussion indicates, are considered critical. Others are felt to be highly desirable. In approximate order of priority, these requirements are listed as follows:

a. Program Interrupt

b. Remote Data Entry

c. Buffered Input and Output

d. Random Access

e. Compiler Programs

f. Magnetic Tape Storage

g. Ultra-high Reliability

h. Solid State

i. Microsecond Access Time

j. Expandable

k. Floating-Point Capability

l. Paper Tape Input and Output

m. Print and Plot Out

n. Record of Satisfactory Performance

o. Compatible With IBM 729 Tapes

p. Maintenance

q. Moderate Cost

r. Medium Size

2. Discussion of the Criteria

The following discussion indicates the reasons for the selection of these particular criteria. The most critical established an immediate basis for eliminating certain computers from consideration. The remaining formed a basis for judgment. The selected computer was chosen to meet all the critical criteria.

a. Program Interrupt is absolutely necessary in a system of severe, overriding program priorities. This situation will recur and, as a consequence, lower priority programs should not be lost. Remote stations should be continuously operable and routine programs should be concurrently admissible to the computer.

(1) Program Priority

The operator of a remote station will be able to call in and request computer usage at random through the use of program interrupt. He will have top priority and pre-empt other types of computer activities.

Program interrupt will also allow the computer to function with the greatest throughput of information. It will not be necessary to tie up the computer for an emergency

condition because the data processor will continue with its normal functions with the full knowledge that high priority work will be handled immediately by interruption of these functions. It will be necessary to use the computer to compute much general background information which will go directly into storage. This reduced information will be supplied to or used by the analyst on demand. The computer should be able to work on these problems and yet, at all times, have the capability of responding to an instantaneous request.

(2) Housekeeping

In every computer installation there is a great deal of what is known as "housekeeping", which includes transferring information from one tape to another, punching new cards, trying new programs, and debugging programs. Program interrupt allows normal functions to go on until pre-empted and also provides for these functions to continue (without the loss of any information) after the interrupt is satisfied.

(3) Intermittent Programs

Infrequent computations will always be required by the computer. Some of these will involve experimental work

or new attempts at data reduction. These could be accommodated during non-working hours. However, program interrupt will allow these computations to be done without interfering with any request to the computer from a higher priority source.

b. Remote Data Entry is one of the most important criteria because of the potential on-line nature of future requirements. This and other reasons are discussed.

(1) On-line

The computational nature of the future requirements is estimated to be "on-line" or "real time". Problem complexity will result in a continual flow of data to be analyzed and attendant computation to be done. In order to keep up, it will be necessary for the data analyzer to get his computation done as he needs it. Otherwise, in many cases, he will be unable to proceed. In the "on-line" mode, the analyst will be able to recognize the need for computation (or the need for any computer-stored or provided answers) and immediately query the computer from a remote station.

(2) Maximum Computer Utilization

A computer is an expensive and sophisticated electronic system and its fullest justification often is in the fact

that it can handle tremendous volumes of data. Remote stations are essential for maximum utilization because they can feed data and requests into the computer instantaneously and whenever necessary. A computer should not sit idle while its punched tape or punched card input data is being carried to it.

(3) Minimum Dependence on Personnel

The maximum performance of the employees demands the least amount of physical movement from one area to another. A remote data entry station is designed specifically for this purpose so that information may flow without the movement of humans. The analyst uses data, requests data and updates computer-stored information continually in the course of his work and he can most greatly benefit by being able to communicate directly to the computer through the use of these remote data entry stations.

c. Buffered Input and Output provides a temporary storage point for input and output data. Its most essential benefits are discussed.

(1) Simultaneity of Operation

One of the many reasons that make simultaneity of operations mandatory is the number of concurrent users of the

computer. Also, there is much information that must be loaded into the computer every day as it is gathered. Comparable operations of inputting, outputting, housekeeping, printing data, and plotting data will always be going on and very often simultaneously.

(2) Optimization

Optimum data handling can only be achieved through multiple operations which, in turn, can only be done effectively through the use of buffered channels. Through the use of buffering, the slower functions of reading-in and writing-out can go on simultaneously with high speed computing.

d. Random Access provides two very necessary attributes.

(1) Speed of Access to Data

It is essential that certain on-line data be available instantaneously so that it can be manipulated and sent to the requesting remote station within a matter of minutes. The entire system should have this high-speed accessibility. High-speed random access is envisioned as a device capable of carrying all the information that any of the analysts will conceivably be using within any certain period. This means that the analyst can address this

information with no intervention by anyone in the machine room. Any random device would have to be capable of accessing data in a speed of under 100 milliseconds.

(2) Accessibility of Data

The second major consideration in this category is accessibility. Through the use of random access devices, it is quite easy to place the information that will be used within any specified period into this device so that it can be called out immediately on demand. Information can be easily changed within random access memory, moved around, and reformated. An outstanding feature is that the information can easily be updated by the analyst or by the machine operators. Random access devices are peripheral to computers and only computers will be considered that provide them. They are modular in construction so that additional ones may be added as the volume of work justifies it. At present, it is assumed that the storage capabilities needed by the random access devices will be in the order of a maximum of 100 words for 10,000 kinds of information at any one time. This would dictate a storage capability of approximately one million words.

e. Compiler Programs or Automatic Programming Routines are essential to any large, varied, computer complex. The major reasons for their necessity are:

(1) Programming Time Saved

It is difficult to estimate the cost of programming by machine language programs vs. the cost of programming with compiler programs without running through a typical problem. A six-fold time-saving for the simplest of programs is probably a conservative estimate. Because of the limited number of personnel available and because time is always an expensive premium, the use of a compiler program is an excellent answer to a complicated problem.

(2) Minimum Debugging

Only minimum debugging is necessary for a compiled program because these programs have been gone over by the originators in great detail and, in most cases, have already been applied to practical problems.

(3) Accuracy

For the same reason, there is a greater assurance of accuracy and fidelity in the use of these programs.

(4) Program Libraries

Finally, there is the fact that many libraries of automatic programs are now available. Although no other computer facility may be doing the same type of problems, general programs will still be available. It is anticipated that as much as 80% of future programming will be done from compiler programs or portions of programs already written. As new problems arise, new programs must be obtained to handle them. It will be found that the speed of programming has been greatly increased because the computer has compiler capabilities. The future will see less and less programmers who are trained in, or have the capability for, doing machine language programming. In order to insure that this computer will be modern for a period of five to seven years after installation, it is preferred that it be able to use this new technique.

f. Magnetic Tape Storage. Storage on magnetic tape is a definite "must" for this computer. The amount of information and data available, and becoming available, dictates this requirement. The amount of reduced data is vast. The only good way to store this information for computer usage (without going into prohibitive expense) is by the use of magnetic tapes. The maximum time to search a tape is considered to be approximately six

minutes. The maximum over-all time usually involved in obtaining a tape from secondary storage, placing it upon a tape handler and getting ready to find the block of information upon it, is in the order of fifteen minutes. Therefore, in something like twenty minutes all the information that has been placed upon tape can be found.

g. Ultra-high Reliability is one of the overriding criteria for this computer. Because of the vital role that it will fulfill, and because the work done is of such a timely nature, it is absolutely necessary that a computer be reliable in operation, speed and accuracy.

h. Solid State is a requirement because of the following reasons:

(1) Reliability

The reliability of solid state transistorized devices is accepted. Mean times to failure of transistorized devices are in the order of ten (10) times greater than that of devices with thermionic tubes.

(2) Minimum Heat Dissipation

Minimum heat dissipation is highly desirable. A solid state computer is preferred because its heat dissipation is in the order of five (5) times less than that of the thermionic type.

(3) Minimum Size and Mobility

As a general rule, all things equal, smaller sizes and mobility are preferred. This adds a small degree of versatility not available in large, cumbersome equipment. The non-mechanical components of a solid state computer are at least half the size of electron tube types.

(4) Modern

Computer capabilities and designs improve almost daily. A solid state computer implies the latest available capability.

(5) Expandable

A solid state computer is suited for expansion because additional components can usually be run on the power supply provided or, if necessary, by means of a small additional unit. In many cases, components can be added to existing logic boards.

(6) Speed

The speed of solid state switching devices is on the order of a million times faster than non-solid state switching circuits. Solid state logic is preferred to provide a high enough speed to do computational work within minimum reasonable times.

i. Microsecond Access Time is essential in this computer because the volume of computations to be handled is large and will continue to get larger.

(1) Complete Computational Operation

It is essential that high-speed operation be an outstanding characteristic of the chosen computer because it is only with a high-speed device that all anticipated computations can be performed. Security is a severe restriction. Also, the unique type of problem cannot be readily handled by other facilities.

(2) On-line Operation

The only satisfactory way to conduct an on-line operation is to get the desired data to the requester in the absolute minimum of time. In a flow system such as envisioned for the Center, it is necessary that this information be provided as soon as it is possible.

(3) High Density Operation

The Center is routinely called upon to handle vast amounts of computational activity in short emergency periods. This type of activity dictates a computer that must be able to quickly complete the job and get the right answers to the right people.

j. Expandability is an exacting requirement of this computer. There are growing numbers of ways to gather data and ways to gather much more data per mission. In order to handle this anticipated load, it is essential that a computer be modular in construction with vast capabilities for expansion. It is imperative that it handle continually increasing amounts of data within a reasonable period of time.

k. Floating-Point Capability is one of the major features desirable for computation. This may be achieved in two ways:

(1) Floating-Point Hardware

Floating-point hardware is a built-in addition to the central processor unit. Some computers have it as an option and still others have a capability of having a floating-point installed. The use of this hardware makes decimal computation very simple and extremely fast. It is simple from the standpoint of programming and fast from the standpoint that it is automatic.

(2) Floating-Point Routines

The alternative to floating-point hardware is Floating-Point Routines. These are branches of programs laid out so that the computer will handle and keep track of the decimal point. The drawback to this approach is the

fact that it takes quite a bit longer to do computations. For instance, a typical multiplication with floating-point hardware might take 40 microseconds, whereas, the same multiplication using the floating-point routine would take 400 microseconds. If this speed is not essential, it would be worthwhile to save the money that would have to be paid for the floating-point hardware. Here speed must be balanced against cost. Additionally, floating-point routines also take more storage, since there are usually 50 or 60 instructions. The accuracy, in both cases, is the same.

l. Paper Tape Input and Output to the computer must be provided because present equipment produces punched paper tapes which are in turn used as inputs to the computer. It is anticipated that the use of punch paper tape will continue after the arrival of the new computer because of the fact that many of the machines that are, or that will be, utilized with the new computer are paper tape producers.

m. Print and Plot Out

Current ouput is in a printed and plotted form. It is necessary that a printer with a high-speed capability be provided in order to keep up with the increased output of an advanced type of

computer. In addition, there must be some type of printing and plotting mechanism at many of the remote stations so that direct requests can be answered immediately at these remote stations. In other cases, where a very large amount of printing or plotting is necessary, it may be done in the computer room and physically brought to the requester.

n. Record of Satisfactory Performance. Another criterion is the record of satisfactory performance by the computer and by the company which manufactures it. Some computers have been evaluated which are not on the market yet. In this case, serious consideration was given to the ability of the producer to manufacture the data processing systems discussed. It is a requirement that the delivered computer be capable of going immediately to work without having to be debugged and reworked.

o. Compatible With IBM 729 Tapes. Compatibility with the IBM tape format (Model 729 Tape Handler) is preferred because that tape handler is so widely used and because tape formats of that type are becoming so universally used. By holding to this requirement, tapes can be produced that can be used by most other facilities. In addition, information from other sources written on magnetic tape in this form can be readily utilized.

p. Maintenance

Adequate maintenance is necessary because of the very complicated array of machinery in a computer. There are two major types of maintenance performed:

(1) Contract Maintenance

All manufacturers require that rented equipment be maintained by their own personnel or by personnel trained under their supervision. Since they own the equipment, they are responsible for it. In addition, most contracts, at present, are written so that the customer pays only for rental during the time the computer is up. Consequently, the manufacturers insist on having their own maintenance crews so that the computer will be available when needed by the customer.

It has been recognized that there are certain security regulations that will have to be considered if contract maintenance personnel are to be used. Negotiations, from this standpoint, have been carried on with several computer manufacturers and, in some cases, it is believed that the suitable arrangements can be made.

(2) Owner Maintenance

If a computer is purchased, maintenance is assumed by

the owner. In this case, the computer manufacturer will train representatives of the purchaser in maintenance procedures. In addition, the manufacturer will provide additional and updating information on this computer or on these computer systems.

q. Moderate Cost. It is felt that a moderate cost computer should be recommended. . . if such a computer could be found that would satisfy all requirements. This type has been found and it does fall within the specified criteria herein listed.

r. Medium Size. A medium-sized scientific computer is preferred by the nature of the computational problem. This choice is based on the fact that the workload to be encountered, in the near and distant future, is of such complexity and volume that it can be most efficiently handled by a medium-sized computer.

From an empirical viewpoint, the present computer is actually on the fringe of the medium-size and the small-size computers. Based on this, it was decided that a computer at the other end of the scale (the high side of the medium computer) would be appropriate for anticipated computational jobs.

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Computers Evaluated

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B. COMPUTERS EVALUATED

The following computers were considered in the evaluation and selection of a machine for use in the computational facility:

1. AUTONETICS
   a. Recomp II
   b. Recomp III

2. BENDIX
   a. G-15
   b. G-20

3. BURROUGHS
   a. 205
   b. 220
   c. B-5000

4. CONTROL DATA CORPORATION
   a. 160-A
   b. 924
   c. 1604

5. DIGITAL EQUIPMENT COMPANY
   a. PDP-1

6. EL-TRONICS

   a. Alwac III-E

7. GENERAL ELECTRIC

   a. 210

   b. 225

8. IBM

   a. 650

   b. 704

   c. 705

   d. 709

   e. 1401

   f. 1410

   g. 7070

   h. 7072

   i. 7074

   j. 305

   k. 1620

   l.

9. MINNEAPOLIS-HONEYWELL

   a. MH-800

   b. MH-400

   c. MH-1000

10. NATIONAL CASH REGISTER

a. 304

b. 304-B

c. 310

d. 315

e. 390

11. PHILCO

a. 2000

12. RAMO-WOOLDRIDGE

a. 400

b. AN/RUYK-1

13. REMINGTON RAND

a. Univac I

b. Univac II

c. Univac III

d. 490

e. Univac 1103-A

f. Univac 1105

14. RCA

a. 301

b. 501

c. 601

15. ROYAL McBEE

a. 4000

b. 9000

16. SYLVANIA

a. 9400

[redacted]

Recommended
Computer

C. THE RECOMMENDED COMPUTER

1. First Order Selection

All computers were judged against the 18 criteria mentioned previously. As a result, the list was narrowed to six computers that might meet the requirements of the system. These six, shown on Table I, were further evaluated against the eighteen criteria. The six computers that were deemed capable and suitable for the consideration for use were:

a. IBM 7072

b. Burroughs B-5000

c. CDC 924

d. Univac 490

e. Bendix G-20

f. GE-225

2. First Order Comparison

The obvious point noted from Tables I and II was the fact that there were eleven criteria which all six of these computers met. This was probably due to the fact that they were chosen to perform in a particular system. The criteria common to all six were:

a. Program Interrupt

b. Buffered Input and Output

TABLE I - CRITERIA FOR COMPUTER EVALUATION

	SELECTION CRITERIA	IBM 7072	BURR. B-5000	CDC 924	UNIVAC 490	BENDIX G-20	GE 225
a	Program Interrupt	x	x	x	x	x	x
b	Remote Data Entry	?	?	Probably	x	x	x
c	Buffered Input and Output	x	x	x	x	x	x
d	Random Access	Disk	No	Disk	Drum	Disk	Disk
e	Compiler Programs	Fortran	Algol	?	Algol	Algol	GE-Com
f	Magnetic Tape Storage	x	x	x	x	x	x
g	Ultra-high Reliability	x	?	x	x	?	?
h	Solid State	x	x	x	x	x	x
i	Microsecond Access	x	x	x	x	x	x
j	Expandable	x	x	x	x	x	x
k	Floating Point Capability	H	H	R	R	H	H
l	Paper Tape Input and Output	Special Order	Special Order	x	x	x	x
m	Print and Plot Out (local and remote)	?	?	Probably	x	x	?
n	Record of Satisfactory Performance	x	?	?	x	?	?
o	IBM Tape 729 Compatibility	x	x	x	x	No	x
p	Maintenance	x	x	x	x	x	x
q	Moderate Cost	x	x	x	x	x	x
r	Medium Size	x	x	x	x	x	x

NOTE: R-Routine; H-Hardware; x-Yes; ?-Doubtful

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c. Magnetic Tape Storage

d. Solid State

e. Microsecond Access

f. Expandable

g. Floating-Point Capability

h. Paper Tape Input and Output

i. Maintenance

j. Moderate Cost

k. Medium Size

On the other hand, there were seven criteria not common to all six computers. The first two of these were most critical and formed a good basis for elimination of at least two of the six computers from further consideration. The criteria not common to all six were:

l. Remote Data Entry

m. Random Access

n. Compiler Programs

o. Ultra-high Reliability

p. Print and Plot Out

q. Record of Satisfactory Performance

r. IBM Tape 729 Compatibility

3. The Univac 490

On the basis of the analysis, the decision was made that the Univac 490 was by far the most suitable computer to be used in the fulfillment of total system requirements. The 490 is a Remington Rand development based on the proven design and performance of their Model 460 computer which has been utilized by the Naval Tactical Data System at the Naval Electronics Laboratory in San Diego for over a year. Except for certain details of its memory cycle, it is identical to the Univac 1206 Military Real Time Computer (AN/USQ-20). It was specifically designed as a real time computer to operate with off-line equipment and with remote inquiry in order to satisfy the requirements of the Naval Tactical Data System. The requirements of the system are also real time. This, therefore, was one of the large factors affecting this decision. The Univac 490 was the only one of the six computers that possessed all of the eighteen attributes specified as criteria.

4. Details of the Evaluation

Further comments about the six computers are made in Table II. The point of interest in this tabulation is the fact that, although many criteria were met, there was a great deal of difference in the capabilities of the respective computers as they applied to apparently common criteria.

Examining the criteria point-by-point is of interest:

a. Program Interrupt - All of the computers have program interrupt capabilities. The Univac 490 provides this capability with the addition of no external hardware. This was a specific requirement of the Naval Tactical Data System. It means that any remote or local requesting station can, on a pre-set priority basis, process its requests immediately. The 490 has the largest capability for this type of activity. It has twelve input-output channels and therefore can readily handle many remote stations with only a few multiplexes per channel. The others, with the exception of the GE-225, were very limited in this respect.

b. Remote Data Entry - The 490 was specifically designed for remote entry as part of the Naval Tactical Data System. The types of external hardware and requests made upon NTDS are the same or similar to those required for this system. Remote data entry, in the strictest computational sense, is not common in commercial computers. The other two computers that call out remote data entry capabilities are the Bendix G-20 and the GE-225. However, it appears that the term is really being used in a business sense rather than in a computational scientific sense. In other words, it is being used mainly for

look-up rather than a combination of look-up and compute within the central processor.

c. Buffered Input and Output - All of the computers have buffered input and output. The 490 follows a Remington Rand concept of full buffering with no additional equipment or expense.

d. Random Access - All of the six computers have random access with the exception of Burroughs which will probably have one in the future. The Univac is the only one that utilizes a drum which has smaller storage capabilities than a disk file. However, large drums can be added as work increases. In addition, Univac is making a disk file which can be added with no reworking of the basic computer at a later date. At present, a single drum would appear to provide the desired storage capability for random access.

e. Compiler Program - The Algol Compiler program, which is considered essential, is standard with Univac. Remington Rand is preparing large libraries of compiler programs for the Real Time Computers. It is under contractual agreement to provide compiler programs to some of the present purchasers of the 490.

An important point to consider in compiler programs is the

number of tape units necessary to do the compiling. The Univac only requires four, which is equal to the number required to handle the computing load. Most of the other computers take more tapes for the compiler than for processing, meaning that tape units, in addition to the four required for processing, would have to be rented or purchased to handle the compiling program and that they would sit idle at other times. The Univac ability to use the minimum number of tape units for compiling is a definite advantage.

f. Magnetic Tape Storage - All of the units considered have magnetic tape storage. Their magnetic tape units are more or less the same, and it is more a matter of the cost and the controls to handle them.

g. Ultra-high Reliability - This facility should stand by itself since its data processing cannot readily be done elsewhere. This requirement is essential because of the large and important part that computation plays in timely operation. There are only two companies that are experienced in great depth in computers of this type and magnitude. They are IBM and Remington Rand. The IBM 7072 has not been delivered as yet. However, it is very close to their 7070 system and the Univac 490 is very similar to several other systems of Remington Rand.

It is difficult to assess the reliability of the other computers because they have not had much time in the field. There are several GE-225's in operation but they have only been delivered within the last few months.

h. Solid State - All six computers under final consideration are transistorized. The 490 is one of a series of solid state computers built by the Remington Rand Univac Division. These range from the solid state 80/90, which is a relatively small business machine, up to the giant LARC computers. The company has over 100,000 hours of operating experience on real time computers.

i. Microsecond Access - All the computers have microsecond access. However, the General Electric 225 is actually so much slower than the rest and so slow in comparison to the state-of-the-art that it is doubtful that the computer would be able to handle the increasing computational load. The GE-225 is slow because, as a business computer, it is not required to achieve high speeds.

j. Expandable - All of the units are expandable in some measure. One of the great advantages of the 490, however, is the fact that the unit was designed to be expandable as real time operations increase. The twelve input-output channels and two

communication channels give it a great deal of flexibility without the addition of exchanges. The 7072 and the Bendix G-20 would require quite a bit of additional expense in order to provide equivalent capabilities.

k. Floating-Point Capability - All of the computers provide the floating-point capability. Four of them provide floating-point hardware and two achieve the floating-point arithmetic through the use of routines. Of course, the four with hardware also provide floating-point routine if one does not wish to rent the hardware. On several of the machines, hardware is provided at an additional cost, and on a couple of them, hardware is standard. In the case of the Univac, no hardware is available for floating-point. All floating point operations are done by a routine. As stated, the major mission of this computer is to do computation. Floating-point hardware can achieve this much faster than floating-point routine. The Univac 490, however, is considered to be acceptable even though the hardware is not provided and cannot be added because the speed of mathematical operations using a routine is almost as fast as other computers with the floating-point hardware.

The bulk of the work involves "from-to" measurements and it is anticipated that only the complicated perspective transformation

need be done in a floating-point routine. The voluminous filling in of the "from-to" table can be done, most effectively, by fixed point operation.

l. Paper Tape Input and Output - The Univac has been providing this for many years on computers and it is again available on the 490. As already indicated, some of the computers studied have not yet been delivered and those that have, have not always had the paper tape input and output, although it could conceivably be added later, if necessary.

m. Print and Plot Out - All of the computers have high-speed printers for local use. Remote stations are presently available only with Univac. Although IBM, GE and CDC recognize the need for this remote communications link, none have designed these into their systems, but would supply them for the customers who would pay for development. Perhaps the most familiar remote print-out application is the (Univac) Uniset that is used throughout the country for airline reservations systems.

n. Record of Satisfactory Performance - The only manufacturers that have any record of satisfactory performance in the medium-sized scientific computational field for this type of computer are IBM and Univac. Once again, this is not intended to overlook the engineering capabilities of the other manufacturers.

o. IBM Tape Compatibility - All of the units with the exception of Bendix have the IBM tape compatibility requirement.

p. Maintenance - This is provided by all of the six manufacturers. However, Burroughs and Bendix are just making their entry into the large computer field and General Electric is making its entry into the computer field for the first time. The only companies that maintain large staffs of highly trained technical personnel throughout the country are IBM and Remington Rand. This does not mean that there are not good, competent personnel in the other companies, but it does indicate that their service facilities are much more limited.

q. Moderate Cost - Detailed cost figures on a rental basis are provided in Section D - General Purchasing Factors and Associated Costs. Any of the equipment that is not available for each of the six computers has not been included in the total. This has been done so that an across-the-board comparison can be made. The major items not in the total are:

(1) Random Access and Control Units - These devices vary so much in capacity and cost that it is unwise to include them until a specific model for each manufacturer is determined. Many of the manufacturers have more than one Random Access Device.

(2) Paper Tape Input - Prices are not available for all six of the computers being considered.

r. Medium Size - All six computers have approximately the same size.

TABLE II DETAILED COMPARISON OF CAPABILITIES

		IBM 7072	BURROUGHS B-5000	CDC 924	UNIVAC 490	BENDIX G-20	GE 225
a	PROGRAM INTERRUPT **	More time consuming than in other systems	Should function very well	?	In operation on a similar computer	In operation	Extra Hardware $75/ month
b	REMOTE DATA ENTRY	Possibly on special request at additional cost	Provided but not proven	?	In operation on a similar computer	Announced but not tried	Not tried yet
c	BUFFERED INPUT AND OUTPUT **	Requires an additional unit	Requires very expensive additional units	?			
d	RANDOM ACCESS	Proven Disk	None	Disk	Proven drum Disks to be announced	Disks	Disks
e	COMPILER PROGRAMS	Fortran IBM Language; not as useful as Algol 6 transports req.	Algol Universal Algebraic language no transports req.	4 transports probably req.	Algol Universal Algebraic language 4 transports req.	Algol Universal Algebraic language 4 transports req.	GE - COM GE language like Algol 6 transports req.
f	MAGNETIC TAPE STORAGE **	Plastic	Plastic	Plastic	Plastic & metal	Plastic	Plastic
g	ULTRA HIGH RELIABILITY	Excellent record over long period for computers of this type	Doubtful. A machine with new principles; may require substantial debugging	Excellent record over short period for large and small computers	Excellent record over long period for computers of this type	Convincing proof unavailable	Convincing proof unavailable
h	SOLID STATE **						
i	MICROSECOND ACCESS **	Six	One	Six	Six	Six	Eighteen
j	EXPANDABLE **	Expanded capabilities usually provided by off-line satellite	4 channels max.	?	Real time computer designed for expandability	4 channels max.	No proven capability

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TABLE II DETAILED COMPARISON OF CAPABILITIES (con)

		IBM 7072	BURROUGHS B-5000	CDC 924	UNIVAC 490	BENDIX G-20	GE 225
k	FLOATING POINT CAPABILITY**	Standard	Double Precision hardware is standard	Routine only	Routine only Routine perfected and in use	Optional	Optional - Hardware costs 12% of main frame. Hardware speed slower than routine on 490.
l	PAPER TAPE INPUT AND OUTPUT **	Capability usually provided by a satellite computer (1401)					
m	PRINT & PLOT OUT (LOCAL & REMOTE)	Possibly on Special Request	Possibly on Special Request	?	In operation on a similar computer	Special Request	Special Request
n	RECORD OF SATISFACTORY PERFORMANCE	Excellent record for both machines and service. The 7072 is in operation	Have not delivered any computers of this type	Reliable information indicates that this computer may never be made - and if so in limited production	Excellent record for both machines and service. A similar computer is in operation	Have only delivered a few in recent months	Total output of computers is within GE facilities have rejected this model.
o	IBM TAPE COMPATIBILITY					No	
p	MAINTENANCE **	Excellent history of medium size computer service	First computer of this magnitude	Limited, representatives throughout country	One of the larger companies	First computer of this magnitude	First computer
q	MODERATE COST ON A RELATIVE BASIS **	1	.97	.87	.74	.63	.67
r	MEDIUM SIZE **	Usually being recommended for installation with satellite 1401		?			

Note: ** Common Criteria
? No information available or questionable
Blank Same as table I

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Gen'l Purch.Factors
and Associated Costs

D. GENERAL PURCHASING FACTORS AND ASSOCIATED COSTS

	IBM 7072	BURROUGHS B-5000	CDC 924	UNIVAC 490	BENDIX G20	GE 225
CENTRAL PROCESSOR	7105-2	B5280	924 16k words	490 16k words	G-20B 8k words	C225 E 16k words
	$7,775	$6,400	$14,600	$10,000	$7,630	$4,900
AUXILIARY MEMORY MODULE	1) 7301-22 10k words 2) 7301-11 5k words	4 req. - B460 4k words ea.	NOT REQUIRED	NOT REQUIRED	MM-10B 8k words	NOT REQUIRED
	$10,300	$5,000			$2,070	
CONTROL CONSOLE	7150-1	INCLUDED	INCLUDED	INCLUDED	CC-10	INCLUDED
	$300				$300	
MAGNETIC TAPE TRANSPORT (4 minimum)	729 II 6 units	B422 4 units	1607 4 units	IIA - 729	1 MT-10B 1 MT-10C	T225D 6 units
	$4,200	$3,200	$5,050	$2,000	$3,320	$10,050
MAGNETIC TAPE BUFFER	7624	INCLUDED	INCLUDED	With Power Supply	INCLUDED	U225B
	$2,050			$2,000		$1,030
HIGH SPEED PRINTER	7400 150 LPM	B 321 650 LPM	1612 1000 LPM	600 LPM	LP-11 500 LPM	Anelex P225 A 900 LPM
	$950	$1,200	$1,840	$500	$1,430	$1,275

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D. GENERAL PURCHASING FACTORS AND ASSOCIATED COSTS (cont'd)

	IBM 7072	BURROUGHS B-5000	CDC 924	UNIVAC 490	BENDIX G-20	GE 225
PRINTER BUFFER	INCLUDED	INCLUDED	INCLUDED	490 PRINTER BUFFER	PC-10 not needed when DC-11 is used	INCLUDED
				$1,450	LA-10 $40	
PAPER TAPE INPUT *	SPECIAL	Probably same as 220 1000 ch/sec Model 440	INCLUDED	(Ferranti) 300 ch/sec 100 ch/punch	PT-10 500 ch/sec 100 ch/punch	G225-B 1000 ch/sec
		$225		$300	$525	$230
I/O BUFFER	7600-1	4) B2582 max. for 4 independent channels	INCLUDED	INCLUDED	NOT REQUIRED	NOT REQUIRED
	$1,400	$11,000				
CARD READER	7500 500 CPM	B 124 800 CPM	1609 100 CPM	600 CPM	IBM 088-3 650 CPM	D225B 400 CPM
	$400	$400	$1,175	$350	$390	$375
CARD I/O BUFFER	NOT REQUIRED	INCLUDED	INCLUDED	490 CARD BUFFER	PA-10 RA-10	Provided for Read E225E Punch
				$1,600	$105	$335
RANDOM ACCESS *	1301 Disk File	Up to 50 units. About 30×10^6 ea.	(Bryant disk) 200×10^6 ch	FH-880 4×10^6 ch	DM-10 4 disk 11×10^6 ch	M640A Disk 19×10^6 ch
		$1,000	$8,600	$2,000	$3,375	$1,650

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D. GENERAL PURCHASING FACTORS AND ASSOCIATED COSTS (cont'd)

	IBM 7072	BURROUGHS B-5000	CDC 924	UNIVAC 490	BENDIX G20	GE 225
RANDOM ACCESS CONTROL *	File Control	NOT ANNOUNCED	POSSIBLY INCLUDED	Control & Synch.	NOT REQUIRED	M225B
				$1,340		$900
CONTROL BUFFER	2802 Power Converter	NOT REQUIRED	NOT REQUIRED	NOT REQUIRED	DC-11	NOT REQUIRED
	$400				$2,350	
CARD PUNCH	7550 250 CPM	B 303 100 CPM	Included in 1609	150 CPM	IBM 544 250 CPM	E225E 200 CPM
	$550	$450		$500	$522	$440
FLOATING POINT HARDWARE	STANDARD	STANDARD DOUBLE PRECISION	NONE	NONE	STANDARD	OPTIONAL
						$600
CHANNELS (max.)	2	4	3 inputs 3 outputs	12 2 Comm.	4 [redacted]	13
STORAGE (words)	5k to 30k	4k to 32k	8k to 32k	16k or 32k	4k to 32k	2k to 16k

D. GENERAL PURCHASING FACTORS AND ASSOCIATED COSTS (cont'd)

	IBM 7072	BURROUGHS B-5000	CDC 924	UNIVAC 490	BENDIX G-20	GE 225
MINIMUM TAPE TRANSPORTS FOR COMPILER ASSEMBLY	6	0	4	4	4	6
BASIC CYCLE TIME (MICROSECONDS)	6	1 (parallel multiple clock pulse)	6.4	6	6	18
EXECUTE SINGLE PRECISION ADD FIXED . . . . . . FLOATING	X 20	X 5	NOT ANNOUNCED	12 400	0 2	36 400
EXECUTE SINGLE PRECISION MULTIPLY FIXED . . . . . . FLOATING	X 64	X 37	NOT ANNOUNCED	53 420	24 33	378 600
NO. DELIVERED OR 1st DATE OF DELIVERY	SIMILAR TO 7070 & 7074	NASA July 1962	NOT ANNOUNCED	SIMILAR TO NTDS 460 Dec. 1962	1	6
BASIC MACHINE TYPE	SCIENTIFIC	BUSINESS	SCIENTIFIC	SCIENTIFIC	SCIENTIFIC AND BUSINESS	BUSINESS

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D. GENERAL PURCHASING FACTORS AND ASSOCIATED COSTS (cont'd)

	IBM 7072	BURROUGHS B-5000	CDC 924	UNIVAC 490	BENDIX G-20	GE 225
WORD SIZE BITS	10 dec. + sign 53 bits	48 & parity	24	30	32 & parity	20 & parity
MEMORY TAKEN BY PROGRAMMED FLOATING POINT WORDS	NONE	NONE	?	350	NONE	500
DELIVERY	18 mos.	18 Mos.	10 Mos.	14 Mos.	12 Mos.	12 Mos.
F.O.B.	Poughkeepsie	Pasadena or Detroit	St. Paul	St. Paul	Los Angeles	Phoenix
PLOTTER	Special Order	Model 201 Tally No Price Yet	NOT ANNOUNCED	RFQ (used on 460)	?	NOT INCLUDED
PLOTTER BUFFER	Special Order	INCLUDED	NOT ANNOUNCED	RFQ	?	NOT INCLUDED

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D. GENERAL PURCHASING FACTORS AND ASSOCIATED COSTS (cont'd)						
	IBM 7072	BURROUGHS B-5000	CDC 924	UNIVAC 490	BENDIX G20	GE 225
BUFFER FOR 20 REMOTE STATIONS	Special Order	Special Order	Data Display Inc.	NOT REQUIRED	NOT REQUIRED	DATA LINKS NEEDED
EXCHANGE	NOT REQUIRED	1- MEMORY NEEDED 1-I/O Provided	INCLUDED	NOT REQUIRED	NOT REQUIRED	NEEDED
AUTOMATIC INTERRUPT	NOT REQUIRED	NOT REQUIRED	NOT REQUIRED	NOT REQUIRED	NOT REQUIRED	J225 B $75
STORAGE DRUM	NONE	1-B430 Req.	NONE	NONE	NONE	NONE
MONTHLY MAINTENANCE	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED	INCLUDED
APPROXIMATE MONTHLY RENTAL	$28,325	$27,650	$24,665	$21,100	$17,827	$19,005

* Items Not Included in Total

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E. IMPLEMENTATION PROGRAM

Some phases of the total program have been completed. Others will or should be considered upon selection of a computer. The components of the system, which will contribute to making the total system coherent, are as follows:

1. Preliminary Analysis

   The concept of operation, the logic of the system, and a preliminary analysis were presented in two reports. The first discussed the nature of the problem, and the second presented the mathematical foundations of this problem.

2. Detailed Specifications - Due to the fact that the Univac 490 has not been used by anyone but Remington Rand, it is advisable to detail the requirements that it must meet. This is not the usual case in obtaining an off-the-shelf computer, but it is deemed necessary in this case to assure complete satisfaction. The specifications will mainly concern themselves with peripheral capabilities, reliability and the ability of the computer to handle the complex and volumetric problem load to be placed upon it.

3. Programming - Agreement must be reached with the vendor regarding the programs to be provided with the computer. In order to accomplish this it will be necessary to provide as much problem

material as possible. Two other areas of programming are to be analyzed. One is the programming by outside companies, and the other is in-house production.

4. Personnel - The staff necessary for supervision, programming, operation, and maintenance of the computer complex should be determined and a Qualified Personnel Requirements document should be issued.

5. Facility - The architectural aspects of the computer facility (air conditioning, fireproofing, cabling, types of storage space, lighting and other mechanical and electrical considerations) are in process. Attention will now be directed toward the specific computer chosen.

6. Old Computer - The involvements of replacing or retaining the existing computer should be considered.

7. Vendor Facility Survey - At least one visit should be made to the Remington Rand facilities at Saint Paul, Minnesota in order to evaluate the facility and to see the 490 computer in operation. In addition, the details of the specifications should be thoroughly discussed.

APPENDIX

GLOSSARY OF TERMS

ACCESS TIME:

(1) The time between the instant at which information is called for from storage and the instant at which it is delivered;

(2) The time between the instant at which information is ready for storage and the instant at which it is stored.

AUTOMATIC PROGRAMMING:

Technique whereby the computer, itself, will translate a program written in a pseudo language easier for the programmer to use, into a machine-sensible language which the computer may use efficiently.

BRANCH:

A point in the programming routine at which the machine may change its normal sequence of instructions based either on a switch setting or a machine condition, such as a minus result in an accumulator.

BUFFER:

A device which stores information temporarily between an input or output unit and internal storage. This device allows computation to proceed while transfers of data between itself and the input or output devices take place.

COMMON LANGUAGE:

A machine-sensible information representation which is common to a related group of data processing machines.

COMPILE:

To produce a machine-language routine from a routine written in non-machine language by:

(1) Selecting appropriate subroutines from a subroutine library, as directed by the instructions or other symbols of the original routine;

(2) Supplying the "connective tissue" which combines the subroutines into a workable routine;

(3) Translating the subroutines and connective tissue into machine language. The compiled routine is then ready to be loaded into memory and run; i.e., the compiler does not (usually) run the routine it produces.

COMPILER (COMPILING ROUTINE):

An executive routine which, BEFORE the desired computation is started, translates a program expressed in pseudo-code into machine code (or into another pseudo-code for further translation by an interpreter). In accomplishing the translation, the compiler may be required to:

(1) DECODE, to ascertain the intended meaning of the individual characters or groups of characters in the pseudo-code program.

(2) CONVERT, to change numerical information from one number base to another (e.g., decimal to binary) and/or from some form of fixed point to some form of floating-point representation, or vice versa.

(3) SELECT, to choose a needed subroutine from a file of subroutines.

(4) GENERATE, to produce a needed subroutine from parameters and skeletal coding.

(5) ALLOCATE, to assign storage locations to the main routines and subroutines, thereby fixing the absolute values of any symbolic addresses. In some cases allocation may require segmentation.

(6) ASSEMBLE, to integrate the subroutines (supplied, selected, or generated) into the main routine; i. e., to adapt, to specialize to the task at hand by means of present parameters; to orient, to change relative and symbolic addresses to absolute form; to incorporate, to place in storage.

COMPUTER:

Any device capable of accepting information, processing the information, and providing the results of these processes in acceptable form.

DATA PROCESSING MACHINE:

A general name for a machine which can store and process numeric and alphabetic information. (See also COMPUTER.)

DE-BUGGING:

A procedure to establish program accuracy by running the program with selective data to find logical or clerical "bugs" or errors.

DIAGNOSTIC ROUTINE:

A specific routine designed to locate either a malfunction in the computer or a mistake in coding.

EDIT:

To rearrange information; for instance, editing may involve the deletion of unwanted data, the selection of pertinent data, the insertion of information prior to printing, zero suppression, etc. Also tests for validity and reasonableness of information. Example: Day over 31, month over 12.

EXECUTIVE ROUTINE (MASTER ROUTINE):

A routine designed to process and control other routines. A routine used in realizing "automatic coding".

FILE:

An organized collection of information directed toward some purpose.

FILE MAINTENANCE:

The processing of a master file required to handle the nonperiodic changes in it.

FIXED POINT SYSTEM:

A system of handling numbers in which the point separating fractions from whole numbers is located between the same two digit columns. This applies to the decimal, binary or other number systems.

FLOATING-POINT ARITHMETIC:

A technique which operates arithmetically on numbers which are not uniform in the location of the decimal point.

GENERAL ROUTINE:

A specific routine designed to locate either a malfunction in the computer or a mistake in coding.

HARD COPY:

A human-readable document produced at the same time that information is transcribed to a form not easily readable by human beings.

INPUT:

Information (instructions or data) transferred from external storage (usually tape or cards) to the internal storage of the machine.

INTERNAL STORAGE:

Storage facilities forming an integral physical part of the computer, from which instructions may be executed.

INTERPRETER (INTERPRETIVE ROUTINE):

An executive routine which, as the computation progresses, translates a stored program expressed in some machine-like pseudo-code into machine code and performs the indicated operations, by means of sub-routines, as they are translated. An interpretive routine is essentially a closed subroutine which operates successively on an indefinitely long

sequence of program parameters (the pseudo-instructions and operands). It may usually be entered as a closed subroutine and exited by a pseudo-code exit instruction.

LIBRARY PROGRAMS:

An organized collection of standard and proven routines, which may be incorporated into larger routines in a program.

MACHINE LANGUAGE:

(1) A language, occurring within a machine, ordinarily not perceptible or intelligible to people without special equipment or training.

(2) A translation or transliteration of the above into more conventional characters but frequently still requiring special training to be intelligible.

MACHINE LANGUAGE CODING:

Coding in the form in which instructions are executed by the computer. Contrasted to relative, symbolic, and other non-machine language coding.

MAGNETIC TAPE:

A flat ribbon of plastic, which is coated on one side with a material which can be magnetized. Information is stored on the tape by a combination of magnetized spots in certain patterns.

MASTER FILE:

A file of semi-permanent information, which is updated periodically.

MINIMAL LATENCY ROUTINE:

Especially in reference to serial storage systems, a routine so coded by judicious arrangement of data and instructions in storage, that the actual latency is appreciably less than the expected random access latency.

ON-LINE:

Operation of an input/output device as a component of the computer, under programmed control.

OUTPUT:

Information transferred from the internal storage of a computer to output devices or external storage.

POINT:

In positional notation, the location or symbol which separates the integral part of a numerical expression from its fractional part. For example, it is called the binary point in binary notation and the decimal point in decimal notation. If the location of the point is assumed to remain fixed with respect to one end of the numerical expressions, a fixed-point system is being used. If the location of the point does not remain fixed with respect to one end of the numerical expressions, but is regularly recalculated, then a floating-point system is being used.

(Note: A fixed-point system usually locates the point by some convention,

while the floating-point system usually locates the point by expressing a power of the base.)

PROGRAM:

(1) A precise sequence of machine coded instructions for a digital computer to use to solve a problem.

(2) A plan for the solution of a problem.

(3) Loosely, a synonym for "routine".

(4) To prepare a program.

PUNCHED PAPER TAPE:

A strip of paper on which characters are represented by combinations of holes punched across the strip.

RANDOM ACCESS:

Access to storage under conditions in which the next position from which information is to be obtained is in no way dependent on the previous one.

RANDOM ACCESS STORAGE:

A storage technique in which the time required to obtain information is independent of the location of the information most recently obtained; i.e., items do not have to be processed in sequence.

READ:

(1) To copy, usually from one form of storage to another, particularly from external or secondary storage to internal storage.

(2) To acquire information, usually by observing some form of storage. (Note: Usually a process which can be called reading can also be called writing, depending on the point of view of the observer.)

RERUN ROUTINE (ROLLBACK ROUTINE):

A routine designed to be used in the wake of a computer malfunction or a coding or operating mistake to reconstitute a routine from the last previous rerun point, which is that stage of a computer run at which all information pertinent to the running of the routine is available either to the routine itself or to a rerun routine in order that a run may be reconstituted.

ROUTINE:

A set of instructions arranged in proper sequence to cause a computer to perform a desired operation or series of operations, such as the solution of a mathematical problem.

SERVICE ROUTINE:

A routine designed to assist in the actual operation of the computer. Tape comparison, block location, certain post mortems, and correction routines fall into this class. Also called "operation routine".

SPECIFIC ROUTINE:

A routine expressed in specific computer coding designed to solve a particular mathematical, logical, or data handling problem.

STORAGE:

(1) The act of storing information. (See also STORE.)

(2) Any device in which information can be stored. Sometimes called a "memory" device.

(3) In a computer, a section used primarily for storing information. Such a section is sometimes called a "memory" or a "store" (British).

(Note: The physical means of storing information may be electrostatic, ferroelectric, magnetic, acoustic, optical, chemical, electronic, electrical, mechanical, etc., in nature.)

STORAGE CAPACITY:

The amount of information that can be simultaneously retained in a storage (or memory) device, often expressed as the number of words that can be retained (given the number of digits, and the base, of the standard work). When comparisons are made along devices using different bases and word lengths, it is customary to express the capacity in "bits". This number is obtained by taking the logarithm to the base 2 of the number of distinguishable states in which the storage can exist.

(Note: The "storage (or memory) capacity of a computer" usually refers only to the principal internal storage section.)

STORED PROGRAM:

A series of coded operational steps arranged in a particular sequence and placed in memory of a computer so that it can be interpreted and executed.

SUBROUTINE:

(1) In a routine, a portion that causes a computer to carry out a well-defined mathematical or logical operation.

(2) A routine which is arranged so that control may be transferred to it from a master routine and so that, at the conclusion of the subroutine, control reverts to the master routine. Such a subroutine is usually called a closed subroutine. This avoids repeating the same sequence of instructions in different places in the Master Routine. A single routine may simultaneously be both a subroutine with respect to another routine and a master routine with respect to a third. Usually control is transferred to a single subroutine from more than one place in the master routine, and the reason for using the subroutine is to avoid having to repeat the same sequence of instruction in different places in the master routine.

SYSTEM:

(1) An assembly of machines united by some form of regulated interaction to form an organized whole.

(2) A collection of operations and procedures, men and machines, by which a business is carried on.

TEST ROUTINE:

A routine designed to show that a computer is or is not functioning properly.

TRANSISTOR:

A small solid-state semiconducting device, ordinarily using germanium, that performs nearly all the functions of an electronic tube.

UNCONDITIONAL TRANSFER OF CONTROL:

Synonym for "unconditional jump".

UNIT:

A portion of subassembly of a computer which constitutes the means of accomplishing some inclusive operation or function, as "arithmetic unit".

UPDATE:

To modify a master file according to current information, which is often contained in a transaction field, according to a procedure specified as part of a data processing activity.

VERIFICATION:

The process of automatically checking the results of one data recording process against the results of another data recording process for the purpose of reducing the number of errors in data transcription. (See also CHECK.)

VERIFIER:

A device on which a manual transcription can be verified by comparing a retranscription with it character by character as it is being retranscribed.

VOLATILE:

A term descriptive of a storage medium in which information cannot be retained without continuous power dissipation.

(Note: Storage devices or systems employing non-volatile media may or may not retain information in the event of planned or accidental power removal.)

WILLIAMS TUBE STORAGE:

A type of electrostatic storage.

WORD:

An ordered set of symbols which is the normal unit in which information may be stored, transmitted, or operated upon within the computer.

WORD TIME:

Synonym for "minor cycle".

WRITE:

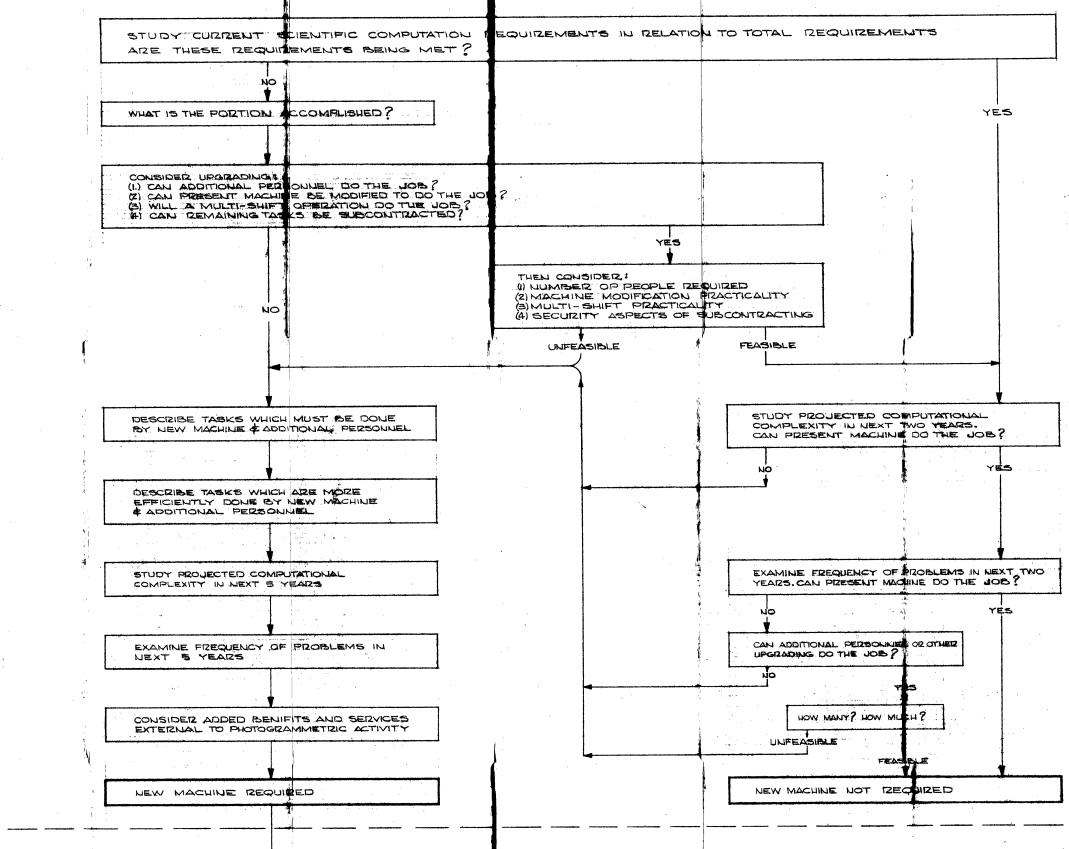
(1) To copy information usually from internal to external storage-- to transfer information to an output medium.

(2) To introduce information, usually into some form of storage. (See also READ.)

ZERO SUPPRESSION:

The elimination of nonsignificant zeros to the left of the integral part of a quantity before printing operations are initiated; a part of editing.

SECRET



OBJECTIVE:
TO DETERMINE IF THE PRESENT ALWAC III COMPUTER IS ADEQUATE TO MEET THE COMPUTATIONAL REQUIREMENTS IN THE NEXT TWO YEARS.

25X1A5a1

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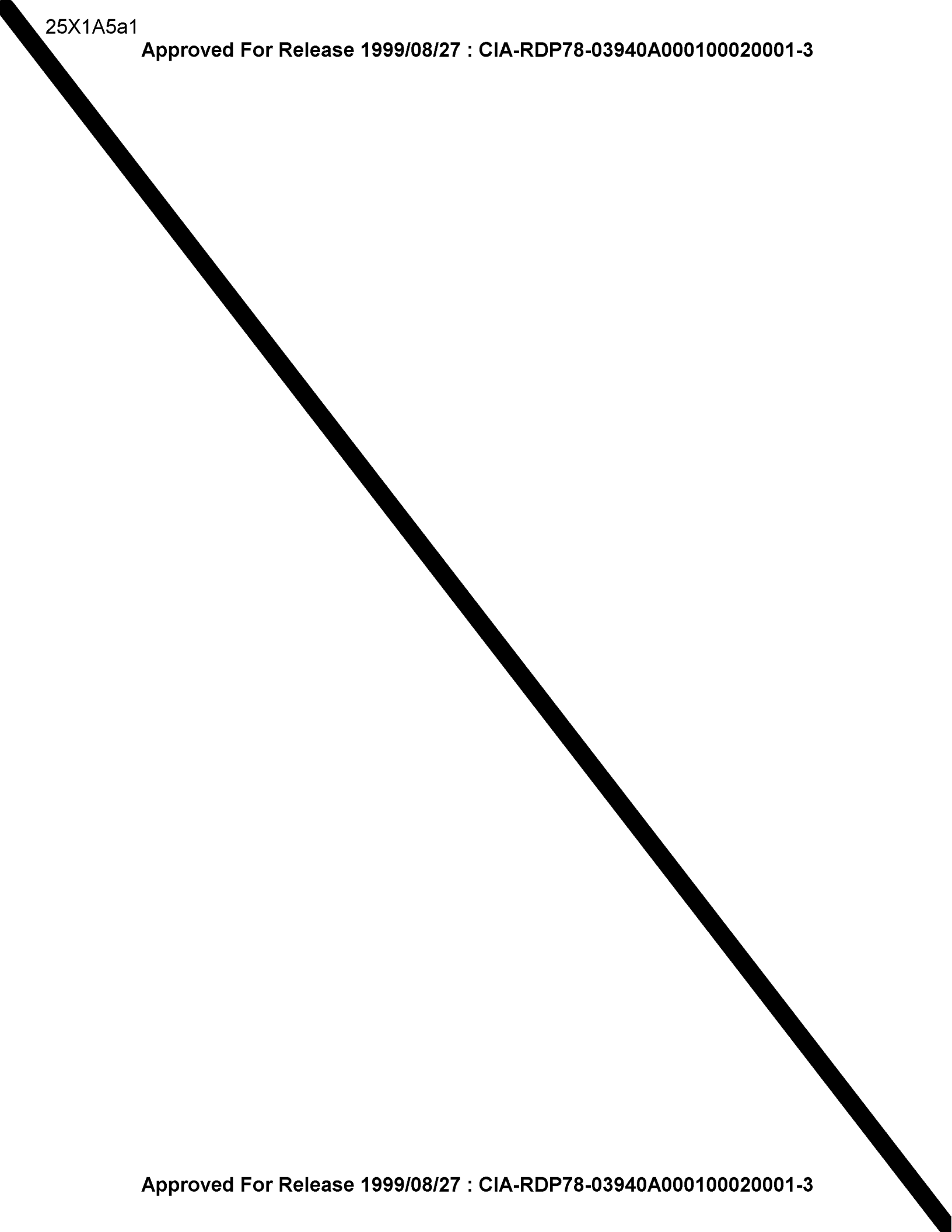
[redacted]

LOGICAL STEPS IN ANALYSIS OF SCIENTIFIC COMPUTATION REQUIREMENTS FOR R.I.C.

FIGURE 1

SECRET



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